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HIGH WATER SPEED TECHNOLOGY DEMONSTRATOR (HWSTD)

DESIGN REQUIREMENTS

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SUBMITTED BY

AAI CORPORATION
A subsidiary of United Industrial Corporation
P.O. Box 126 · Hunt Valley, MD 21030-0126

FOR

David Taylor Naval Ship
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1.0 INTRODUCTION

1.1 General

This report presents the design requirements for the High Water Speed Technology Demonstrator (HWSTD). The HWSTD is a tracked test bed vehicle whose sole function is to demonstrate in a test environment the feasibility of achieving a high water speed. Included in this report are the operating requirements, a brief description of HWSTD, and detailed requirements for the design and fabrication of the HWSTD.

The design requirements presented in this report are based on Section C of DTNSRDC Contract No. N00167-87-C-0033, dated 27 February 1987, the AAI Corporation Technical proposal for the HWSTD, Volume 1, Report No. ER-14469, dated July 1986, and the results of various technical discussions held with DTNSRDC personnel concerning HWSTD requirements, and the characteristics of Government Furnished Equipment planned for use in HWSTD and normal tracked vehicle design practices appropriate for a test bed type vehicle. The hydrodynamic design data and waterjet performance data contained in this report were provided by DTNSRDC, Code 1240. MT883 engine performance data contained in this report was generated based on data provided by MTU.

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The design requirements provided in this report are presented as guidelines for development of the HWSTD. If design activities, and/or receipt of later Government furnished data and performance predictions indicate significant benefits in vehicle weight, cost and performance are feasible, alterations in these requirements will be considered. Should new or modified requirements result, these requirements will be published as revisions to this report. These requirements will be documented by revised and/or new pages and their inclusion in this report will be noted in the change log provided in this report.

1.2 Background

Under Contract N00167-87-C-0033 to the U.S. Navy David Taylor Naval Ship Research and Development Center (DTNSRDC), Code 1240, Marine Corps Programs Office, Bethesda, Maryland 20094, the AAI Corporation is designing, developing, fabricating and testing a tracked amphibious test bed vehicle to demonstrate high water speed performance.

The main objective of the High Water Speed Technology Demonstrator (HWSTD) Program is to develop a technology demonstrator tracked vehicle capable of achieving a water speed of 20 plus miles per hour in Sea State 2. Demonstration of this high water speed capability will be accomplished in a controlled test environment. Land operation of the HWSTD will be limited to operation over the paved roads, secondary roads and trails necessary to gain access to the water testing sites and test support facilities. HWSTD land operation will be at moderate speeds.

The HWSTD will employ many of the components and subsystems previously developed by AAI for the Automotive Test Rig (ATR) vehicle. The HWSTD will be equipped with devices (bow flap, transom flap, side skirts and chine flaps) to alter its physical configuration in the water in order to improve its hydrodynamic characteristics. The basic hull configuration of the HWSTD will be a lengthened version of the ATR hull with these devices installed.

The power pack of the HWSTD, in its Phase I configuration, will be a Government furnished MTU 883 diesel engine (1500-1600 BHP) with cooling system, alternator and pump drive gear box. Engine output will be provided to the gear box which in turn will drive hydraulic pumps that power the land and water drive systems and the other auxiliary hydraulic systems of the HWSTD.

For landborne propulsion the engine driven pump outputs are provided to hydraulic motors that drive final drive units that in turn drive the HWSTD tracks through drive sprockets mounted in the rear of the HWSTD.

Waterborne propulsion is provided by directing the engine driven pump outputs to hydraulic motors driving the three waterjets mounted in the transom flap. The transom flap is deployed hydraulically and is equipped with two rudders to provide steering in the waterborne mode.

Control, speed, direction and steering of the HWSTD will be accomplished by an analog/digital control system. Two primary controllers with a manually operated backup controller will be provided. Driver steering inputs will be accomplished by the use of a hand control grip.

The suspension system of the HWSTD consists of six dual roadwheel stations per side, front compensating idlers with track adjusters, four support roller assemblies, twelve hydropneumatic suspension units, a 17-inch wide roller chain band track and two rear mounted drive sprocket assemblies. The hydropneumatic suspension units are of rotary design and provide for full suspension retraction in the amphibious mode to improve the HWSTD's hydrodynamic configuration. The HWSTD roadwheels are 21 inches in diameter by 3.5 inches in width.

For high speed water operations the HWSTD will be equipped with a deployable bow flap. The bow flap is deployed and retracted by the operation of hydraulic rotary actuators. The deployed configuration of the bow flap will be based on design guidance provided by DTNSRDC.

During water operations the HWSTD hull/suspension cavities will be enclosed by side skirts, permanently mounted on the sides of the hull and deployable chine flaps. The chine flaps are stowed on the hull bottom and rotated into position by hydraulic rotary actuators. The chine flaps lock with the side skirts to enclose the suspension system in its retracted position.

Personnel accommodations provided in the HWSTD will include adjustable seats with seat belt constraints, and hatches with vision blocks at the driver's and commander's stations located in the front of the vehicle.

The HWSTD will also be equipped with the normal tracked amphibian vehicle auxiliary systems including, an engine air system, cooling systems for both land and water operations, an electrical system (28 VDC), a bilge pump system, a fire detection and suppression system, a fuel system, a crew ventilation system, and communication equipment consisting of a vehicle radio (GFE) and crew intercom system (GFE).

In addition to the components from the ATR used in the HWSTD the HWSTD will incorporate the following major items of Government furnished equipment:

MTU MT883 Diesel Engine with gear box and auxiliary systems (Phase I)

DTNSRDC 16-inch diameter waterjets (3)

Refurbished Bird/Johnson Co. Hydropneumatic Suspension Units (12)

John Deere 2116 Score Engine with auxiliary systems (2) (Phase II)

17" wide Roller Chain Band Track

Phase I of the HWSTD program is scheduled for 26 months and will end with AAI and Government testing of the HWSTD. After completion of Phase I and subject to Government approval, Phase II of the HWSTD program will commence. Phase II activities consist of replacement of the MTU diesel engine with two John Deere 2116 Score engines. Phase II of the program is scheduled for 20 months and will conclude with AAI and Government testing of the rotary engine configured HWSTD.

During the HWSTD Program, AAI will provide documentation in the form of technical reports, engineering drawings, a FMECA report, progress reports, a test plan and a vehicle operation and maintenance manual. During Government testing of the HWSTD, AAI will provide technical support.

2.0 OPERATING REQUIREMENTS

2.1 Environment

The operating environment of the HWSTD will be those conditions associated with the test sites planned for evaluation of HWSTD's water speed performance. These test sites are the DTNSRDC facility on the Severn River, Annapolis, Maryland, and the USMC Amphibious Vehicle Test Branch (AVTB) on the Pacific Ocean, Camp Pendleton, California. Testing activities will consist of land operation at moderate speeds over paved roads, secondary roads and ramps to gain access to water testing areas. Vehicle land operations will not include passage of obstacles and operation in vegetation. Slope operations will be limited to a maximum grade of 17% (10°) with continuous operation on a 10% grade (5.7°). The ambient temperature range during HWSTD operations will be between 20°F and 98°F. Water testing will expose the HWSTD to saltwater with a temperature $\leq$ 70°F.

2.2 Test Operations

HWSTD testing will be accomplished by both AAI and Government personnel. Technical support will be provided by AAI during Government testing activities. Water testing will be limited to a vehicle crew of two with appropriate personnel safety devices and support safety craft. HWSTD water testing will require the use of a vehicle check list prior to water operations.

HWSTD test performance will be documented with photographs and video tape and the collection of appropriate engineering performance data.

3.0 HWSTD CHARACTERISTICS

3.1 Configuration

The HWSTD will consist of an aluminum hull with a propulsion system, suspension system, a land drive system, a marine drive system, auxiliary systems and deployable hull appendages to configure the HWSTD for high speed water travel. The hull appendages include, a bow flap assembly, side skirts, chine flaps and transom flap. The bow flap, chine flaps, and transom flap will be extended and retracted by hydraulic actuators.

The land and marine drive systems will be hydrostatic and provide propulsion system power to hydraulic motors that will drive the final drive units and the three transom flap mounted waterjets. Land operations will be based on a maximum gross horsepower of 540 HP. Water operations will be based on a maximum of 1609 gross horsepower, and the achievable hydrostatic marine drivetrain efficiency.

The HWSTD suspension system will consist of Automotive Test Rig (ATR) suspension components and a 17-inch wide roller chain band track (GFE). The suspension system will consist of six, dual roadwheel stations per side. Each station will be employed with a rotary type hydropneumatic suspension unit with wheel travel sufficient to permit suspension system retraction in the water mode. A rotating front idler assembly will accommodate the excess track length during suspension system retraction. Rear mounted sprocket assemblies will apply the land drive system output to the tracks for land operations. Two support roller assemblies will provide support for the return segment of the track on each side.

The bow flap assembly will be configured for stowage in the retracted mode on the hull front. It will be extended to its deployed position, prior to high speed water operations, with hydraulic actuators.

The side skirts will be permanently attached to the hull sponsons and enclose the outboard side of the suspension system in its retracted mode. Side skirts will contain locking features to engage and lock the chine flaps in their deployed position.

The chine flaps will be stored against the hull bottom and rotated into their deployed position by the use of hydraulic actuators. In their deployed position they will lock with the side skirts to retain and enclose the suspension system in its retracted mode during water operations.

The transom flap will be mounted on the rear of the HWSTD and contain the marine drive motors and waterjets. The transom flap will be deployed with hydraulic actuators and have the capability for positioning the flap at an angle of between 2 to 6 degrees below the hull bottom plane. This angle shall be adjustable prior to operation. The transom flap will be equipped with side fences and rudders for water steering.

The propulsion system of the HWSTD will consist of a diesel engine with a pump drive gearbox for driving the drive system hydraulic pumps and auxiliary hydraulic system pumps. The engine will be equipped with an air intake system, an exhaust system, and cooling systems suitable for both land and water test operations. The engine will also drive a generator to provide vehicle electrical power.

Auxiliary systems provided in the HWSTD will include the following:

Engine Air System - Includes filtration and provisions for both land and water operation.

Cooling System - Engine and auxiliary systems cooling for both land and water operation.

Electrical System - 28 VDC with 20 KW generator and (6) 12 volt batteries.

Bilge Pump System - Four pump system (2 electrically driven, 2 hydraulically driven) with a total capacity of 480 gpm.

Fire Detection and Suppression System - Optical sensors and suppressant bottles in engine and crew compartments.

Fuel System - 100 gallon capacity.

Ventilation Fan - Crew compartment ventilation.

Communication System - GFE Radio and two station GFE vehicle intercom system.

Hydraulic System - Provides power to vehicle auxiliary hydraulic components and suspension system HPS units.

The external configuration of the HWSTD will be optimized for water operations. Where possible external protrusions for actuators, hinge points, etc., will be faired or flush mounted. Joints between appendages deployed for water operations and the vehicle hull will be sealed to the maximum extent possible.

3.2 Internal Arrangement

The HWSTD will contain personnel accommodations for a two man crew located in the front of the vehicle. Each crew member's station will be provided with an adjustable seat with a seat belt and shoulder harness, a hatch with vision blocks, and appropriate controls and displays for vehicle operation.

The propulsion system of the HWSTD will be centrally located in the hull and separated from the crew stations by a firewall.

The rear of the HWSTD hull will contain a ramp to provide access to the engine compartment when the transom flap is lowered. Removal of the HWSTD propulsion system will be accomplished through a hatch located in the hull top deck.

3.3 Weight Properties

The desired weight properties of the HWSTD in its high speed water mode operating configuration are the following:

Vehicle Gross Weight: ≤ 35,000 pounds (±5%)

Center of Gravity Location:

Longitudinal - Maximum forward location equal to 53% of the hull bottom length measured from rear end of hull.

Vertical - Desired to be not more than 18 inches above hull bottom.

Basis:

Bow Flap extended, transom flap deployed, chine flaps deployed, suspension system retracted, crew and 50% vehicle fuel load.

Source: DTNSRDC Presentation "HWSTD Hydrodynamics", presented at HWSTD kick-off meeting 3/11/87.

3.4 Performance

The performance goal for the HWSTD is achieving a water speed of 20 plus miles per hour in Sea State 2 conditions.

For design trade-offs of weight, longitudinal center of gravity location and available power the following relationships apply:

Maximum Available Engine GHP = 1609 HP (Phase I Engine) (water mode only).

Vehicle Weight Trade-off - 43 lbs of additional waterjet thrust are required for every 100 lbs of vehicle weight over 35,000 pounds.

Vehicle longitudinal center of gravity location - 76 lbs of waterjet thrust are required for every 1 inch forward shift of the c.g. from the 53% hull bottom length location (see Section 3.3).

Power required for waterjets - See Table 3.4-1.

Source: DTNSRDC Presentation "HWSTD Hydrodynamics", presented at HWSTD kick-off meeting 3/11/87.

Available MT883 engine power characteristics - See Tables 3.4-2 and 3.4-3.

Source: Based on data provided by MTU.

Table 3.4-1 HWSTD Waterjet Input Power Requirements

Vehicle Water Speed, MPH	Total Waterjet Thrust, Lbs (3 Waterjets)	Input/Waterjet		
		Torque Ft-Lbs	RPM	SHP
0	15,479	1405	1151	308
4	13,950	1410	1155	316
6	13,400	1425	1160	320
8	12,900	1445	1170	325
10	12,465	1471	1182	331
12	12,175	1500	1195	340
14	11,750	1535	1210	353
16	11,500	1575	1230	368
18	11,298	1618	1251	385
20	10,575	1607	1251	382
22	9,925	1598	1251	380
24	9,250	1588	1251	378
28	7,881	1571	1251	374

Source: DTNSRDC, 3/27/87

Table 3.4-2 Predicted MTU - MT883 Engine Performance*

AS DELIVERED			FUEL SETTINGS ADJUSTED to provide 9.09% more power	
Power (HP-SAE)	Torque (FT-LB)	Speed (RPM)	Torque (FT-LB)	Power (HP-SAE)
347	1822	1000	1993	380
408	1947	1100	2126	445
472	2065	1200	2254	515
540	2183	1300	2384	590
617	2316	1400	2525	673
695	2434	1500	2653	758
782	2567	1600	2800	853
869	2685	1700	2929	948
961	2803	1800	3056	1047
1025	2832	1900	3088	1117
1084	2847	2000	3102	1181
1141	2854	2100	3112	1244
1193	2847	2200	3105	1301
1244	2840	2300	3096	1356
1291	2825	2400	3081	1408
1334	2803	2500	3057	1455
1380	2788	2600	3042	1506
1418	2758	2700	3008	1546
1447	2714	2800	2961	1578
1466	2655	2900	2895	1598
1475	2581	3000	2817	1609
1241	2102	3100	2292	1353
652	1069	3200	1191	725
0	0	3300	0	0

*Basis: Ambient Air Temp. = 86°F & Fuel Temp = 86°F

Table 3.4-3 Predicted MTU - MT883 Engine Performance (Metric)*

AS DELIVERED			FUEL SETTINGS ADJUSTED to provide 9.09% more power	
Power (kW)	Torque (NM)	Speed (RPM)	Torque (NM)	Power (kW)
259	2470	1000	2698	283
304	2640	1100	2879	332
352	2800	1200	3056	384
403	2960	1300	3229	440
400	3140	1400	3423	502
518	3300	1500	3597	565
583	3480	1600	3796	636
648	3640	1700	3971	707
716	3800	1800	4144	781
764	3940	1900	4189	833
808	3860	2000	4209	881
851	3870	2100	4222	928
889	3860	2200	4210	970
927	3850	2300	4199	1011
963	3830	2400	4180	1050
995	3800	2500	4146	1085
1029	3780	2600	4123	1123
1057	3740	2700	4078	1153
1079	3680	2800	4014	1177
1093	3600	2900	3926	1192
1100	3500	3000	3820	1200
925	2850	3100	3108	1009
496	1450	3200	1015	541
0	0	3300	0	0

*Basis: Ambient Air Temp = 30°C & Fuel Temp. = 30°C

The hydrodynamic performance predicted for the HWSTD and the design trade-offs associated with this performance have been developed by DTNSRDC based on model basin and open water tests of HWSTD hydrodynamic configuration. Based on this DTNSRDC assumes full responsibility for the over water performance of the HWSTD.

During design and fabrication of the HWSTD, DTNSRDC shall be responsible for the analysis and prediction of HWSTD hydrostatic characteristics and hydrodynamic performance based on configuration and weight properties data provided by AAI.

3.5 Special Provisions

The HWSTD shall not be equipped with external automotive lights for land operations. Provisions shall be provided to install a commercial type portable spotlight at the driver's station. The HWSTD shall be equipped with AAVP7A1 type lifting/mooring bits on the top surface.

The HWSTD shall be equipped with front towing lugs compatible with a M113A1 vehicle tow bar. The vertical location of these towing lugs shall preclude contact of tow shackles with the ground with the HWSTD in the squatted mode.

The HWSTD engine grille assembly shall be designed without a breaking surf load requirement and people support load requirement. A simple portable cover for people protection of the grille during non-operation will be provided.

Where feasible, HWSTD top deck items such as grilles, access covers, etc., that require frequent removal for maintenance, should be provided with quick release type fasteners or latches.

4.0 DESIGN REQUIREMENTS

4.1 Materials

The materials used in the HWSTD shall be covered by Government or commercial specifications to the maximum extent possible and suitable in every respect with their intended use in the HWSTD. The use of exotic, proprietary and critical materials shall be kept to a minimum. Maximum utilization of economical materials and fabrication processes is required for the HWSTD. Materials, fabrication processes and assembly techniques used in the HWSTD must consider the effects of saltwater corrosion.

4.2 Parts

The HWSTD shall make maximum use of military qualified standard parts and components with the objective of simplifying maintenance and operation during testing. Where military qualified items are not available or excessive in cost, commercially available parts shall be used as appropriate. Parts selected shall be appropriate for operating requirements, loads and a saltwater environment. Where full exposure to the saltwater environment is required, commercial actuators shall be marinized with a protective coating.

The hydraulic components used in the HWSTD shall be of commercial quality and compatible with the HWSTD hydraulic fluid. The HWSTD shall make maximum use of the parts and components of the Automotive Test Rig (ATR).

4.3 Finishing

Selection of finishing requirements shall be appropriate for the operating environment conditions and duration expected to be encountered by the HWSTD during testing. Definition of the surface treatment, corrosion protection, priming and painting of the HWSTD shall be based on good commercial practice and the guidance provided in MIL-STD-171, Finishing of Metal and Wood Surfaces. Mating elements of the HWSTD exposed to saltwater shall be finished and assembled to minimize galvanic corrosion due to dissimilar metals.

The exterior of HWSTD shall be finished in a desert type camouflage pattern similar in colors and distribution to that used on the AAVP7A1 vehicle. The interior of the HWSTD and its mounted components, except for hydraulic lines and tubing and electrical cabling, will be painted with a light green hydraulic oil resistant paint.

4.4 Safety

The HWSTD shall be designed to eliminate safety hazards to operating and maintenance personnel. Where appropriate, guards, covers, or insulating material will be employed to prevent personnel contact with hot surfaces, and to reduce the potential for exposure to hydraulic fluid leakage and crew station noise levels. The top deck surfaces and the rear ramp and transom flap top surfaces of the HWSTD will be treated with non-skid material to improve personnel footing.

The driver's and commander's stations will be provided with vision blocks for forward and side visibility during high speed water operations. Each crew station will be provided with an intercom box for crew and test support personnel communication. The HWSTD will be equipped with a crew compartment ventilation fan to circulate ambient air during closed hatch operations.

The driver's controls and displays will be located for efficient operation and guards will be provided, as appropriate, to prevent inadvertent operation of switches.

The control system of the HWSTD will be an analog/digital type with two primary controllers and a manually operated back-up controller. Driver steering inputs will be accomplished by a hand control grip. A separate hand operated engine throttle lever will be provided for water operations.

The operating and maintenance manual developed for the HWSTD shall contain appropriate warning and caution notices to alert personnel to potential safety hazards when operating and maintaining the HWSTD. The HWSTD will be equipped with an automatic fire detection and suppression system for crew and engine compartment protection.

4.5 Human Factors

During the design and development of the HWSTD, Human Factors Engineering shall be employed to insure that the performance and health of the personnel operating and maintaining the HWSTD during testing are considered. Human factors design considerations shall be based on the guidance provided in MIL-STD-1472, Human Engineering Design Criteria for Military Systems, Equipment and Facilities to the extent feasible for a test bed vehicle, and within program design requirements and cost limitations.

4.6 Structural Design

4.6.1 Structural Design Criteria

Unless otherwise specified, all land loads given in this structural design requirement section are ultimate design loads at which breakage of parts is expected to occur. The magnitude of these loads includes a safety factor of 1.5. Thus, the maximum applied loads are 67 percent of the ultimate design loads given in Section 4.6.2.

For purposes of calculation the HWSTD gross weight is 35,000 pounds.

4.6.2 Safety Factors

- <u>Definition</u>

$$\text{Safety Factor} = \frac{\text{Design Load}}{\text{Applied Load}}$$

Design Load - The theoretical load at which failure will occur due to material rupture, inelastic failure and collapse, or intolerable permanent deformation.

Applied Load - The static or dynamic (static load times dynamic magnification factor) load.

Required Factors of Safety

Against Permanent Deformation = 1.0

Against Ultimate Failure (Most materials and fabrication methods) = 1.5

Against Ultimate Failure (castings) = 2.0 (castings with close quality control, x-ray inspection and minimum elongation of seven percent = 1.5

4.6.3 Allowable Material Stresses

The allowable material or component stresses used in design calculations shall be based upon specified minimum strength values given in component specifications or MIL-HDBK-5.

Minimum full strength and welded strength properties for 5083 aluminum alloy armor, the planned HWSTD primary structural material, are as shown in Table 4.6.3-1. The heat affected zone of welded joints shall be considered to extend to one inch from the joint. X→

4.6.4 Land Loads

4.6.4.1 Road Loads

The land operating load criteria is based on a semi-empirical procedure developed by the U.S. Army TACOM and defined in AMC Pamphlet, AMCP 706-357, Engineering Design Handbook, Automotive Series, Automotive Bodies and Hulls, dated April 1970. In view of the limited land operations planned for the HWSTD (see Section 2.1) the maximum land load factor was based on the load factor relationship defined for a tracked logistics vehicle given in Section 4.1.4.1 of the AMC Design Handbook.

Based on a HWSTD gross weight of 35,000 pounds (W) and this relationship, the following road loads are established for structural design of the HWSTD.

Load Factor

Maximum Load Factor, $n = 100W^{-.156}$

$$n = 100 \times 35000^{-.156} = 19.55$$

Table 4.6.3-1 Minimum Mechanical Properties of 5083 Aluminum Alloy Armor

Basis	Configurations	Tensile Strength, psi	Yield Strength, psi	Elongation, Percent in 2" Length
Full Strength	Structural Members .5" to 2.0" Thick	45,000	37,000	8
	Structural Members 2.001" to 3.0" Thick	44,000	35,000	9
Welded Joints Δ	Parent Material .5" to 2.0" Thick	40,000	33,000	-
	Parent Material 2.001" to 3.0" Thick	39,000	31,000	-

Basis: MIL-A-46027F(MR)

Δ - Using 5356 filler wire

Road Loads

All vertical and longitudinal loads are applied on the centerline of the track. Lateral loads are applied at the bottom edge of the roadwheel.

Front Idler Wheels (vertical and longitudinal loads applied independently)

Vertical Load = .073 nw

= .073 x 19.55 x 35,000

= 50,000 pounds (up direction)

Longitudinal Load = .048 nW

= .048 x 19.55 x 35,000

= 33,000 pounds (aft direction)

Station #1 Roadwheels

Vertical Load = .1 nW

= .1 x 19.55 x 35,000

= 68,000 pounds (up direction)

Other Station (#2 through #6) Roadwheels (Loads applied individually to each roadwheel)

Vertical Load = .05 nW

= .05 x 19.55 x 35,000

= 34,000 pounds (up direction)

All Roadwheels (Loads applied individually to each roadwheel)

Lateral Load = W/2

= 35,000/2 = 18,000 pounds (inboard and outboard directions)

Hydropneumatic Suspension Units (Vertical and lateral loads applied simultaneously)

Vertical = 4 x 35,000/12 = 14,000 pounds (up direction)

Lateral = 2.5 x 35,000/12 = 7,300 pounds (inboard and outboard directions)

Track Support Rollers (vertical and lateral loads applied independently)

Vertical = 6,000 pounds (up direction)

Lateral = 3,000 pounds (inboard direction)

Final Drive and Sprockets

Torque Load = 75 percent of the total drivetrain torque output for the land mode times a safety factor of 1.5 applied to a single sprocket tooth with tooth wear considered.

Radial Load = .07 nW

= .07 x 19.55 x 35,000

= 48,000 pounds (Applied at centerline of sprocket carrier)

Combined Loads = 6,000 pounds applied radially to sprocket carrier and 3,000 pounds applied laterally (either direction) at the outer diameter of the sprocket.

4.6.4.2 Towing and Lifting Provisions

Static Load = five times the HWSTD gross weight (5 x 35,000 = 175,000 pounds) divided equally between either the four lifting points or the two front towing lugs with the load applied within a 120° cone about the vertical axis of the lifting lug and the longitudinal axis in the forward direction of the towing lug.

The powerpack lifting sling shall be designed based on a lifting load equal to 5 times the powerpack weight, and the load distribution provided by the powerpack lifting points and center of gravity.

4.6.4.3 Vehicle Mounted Components

All loads applied independently.

Vertical loads - Based on static weight of item times the shock factor obtained from Figure 4.6.4-1 for the component weight and location relative to the HWSTD center of gravity. Basis: maximum road load factor and AMC Handbook, AMCP 706-357, Section 4.1.4.1.

Longitudinal Load - Five times the static weight of the component.

Lateral Load - Three and a half times the static weight of the component.

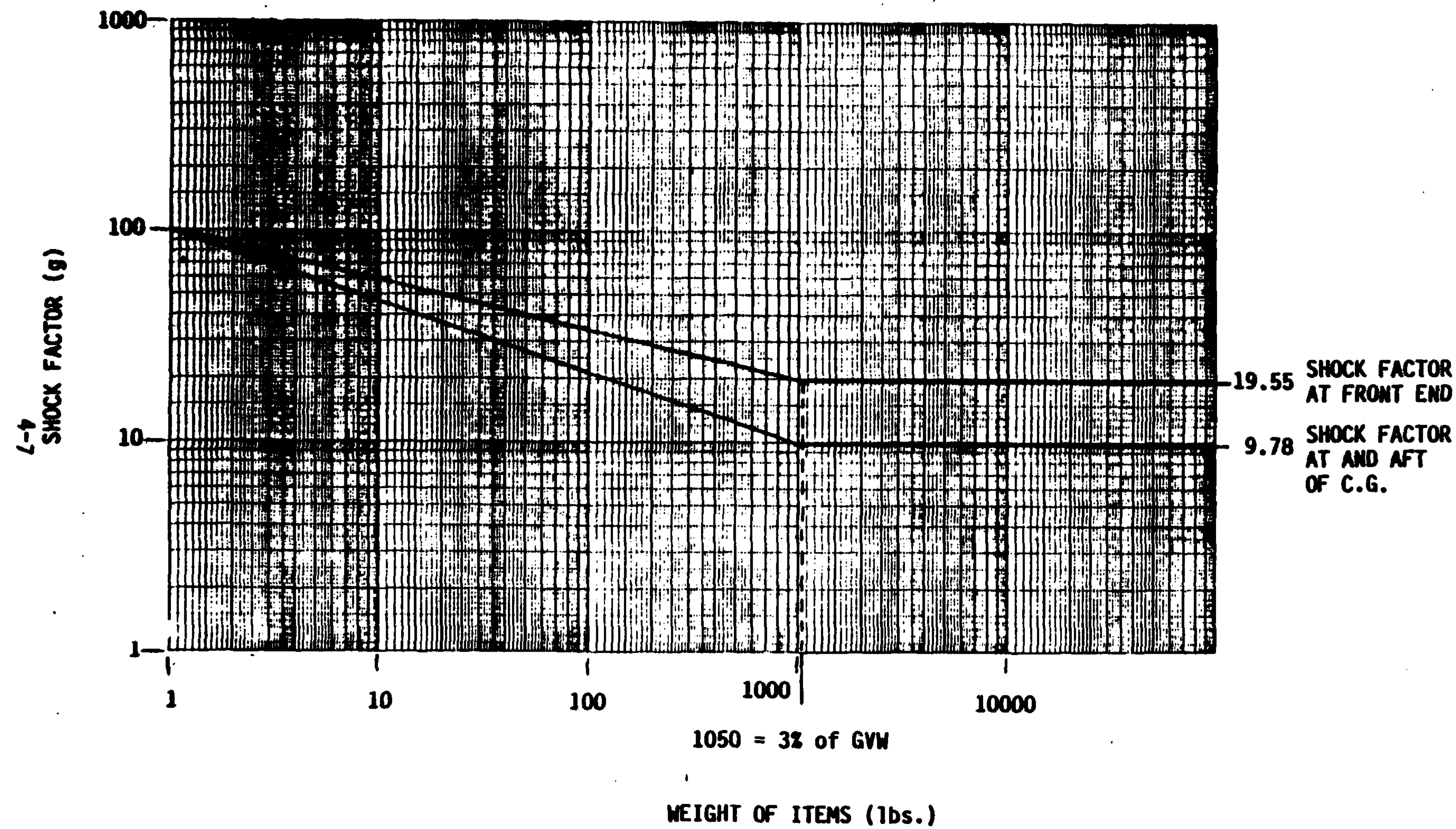

Figure 4.6.4-1 Mounted Component Vertical Shock Factor

4.6.4.4 Hull Structure

The HWSTD hull structure will be designed to withstand the following loading conditions.

Case I - The torsional loads resulting when the HWSTD is supported by two diagonally opposite roadwheel stations, stations #1 and #6.

Case II - All loads resulting from the road loads defined in Section 4.6.4.1.

Case III - The hydrostatic loads resulting from water operation as defined in Section 4.6.5 and the loads resulting from the mounting of the various water operating appendages (bow flap, chine flaps, side skirts and transom flap) in both the stowed (land mode) and deployed (water mode) configurations.

Case IV - The wear and impact loading imposed on the hull sponsons and sides due to track slap.

Case V - The loads resulting when the HWSTD is supported by the #3 roadwheel stations with the HPS unit bottomed out against the sponson bottom and no other roadwheel stations in contact with the ground.

4.6.4.5 Rear Ramp

The HWSTD will be equipped with a lightweight rear ramp which is manually operated. This ramp will not require excessive manpower to open and close. Use of rigging will be acceptable to assist personnel in operating the ramp. The ramp shall be designed to support 350 pounds.

4.6.5 Water Loads

4.6.5.1 General

The HWSTD hull and hull mounted external components and appendages will be exposed in the static water mode to the following hydrostatic loadings based on Section 4.7.4 of the US Army Design Handbook, AMCP 706-357, Automotive Series, Automotive Bodies and Hulls.

$$q = \rho h, \text{ psi.}$$

where ρ = sea water density, .037 lb/inch^3, 64 lbs/ft^3

h = immersion depth, inches

Maximum hydrostatic pressure is expected to equal the following based on a vehicle draft of 60 inches.

$$q_{max.} = .037 \times 60 = 2.2 \text{ psi.}$$

For high water speed operation the stagnation pressure expected to be experienced by vertical surfaces is equal to the following:

$$q_{max.} = \frac{1}{2} \rho V^2, \text{ psi (stagnation point)}$$

where

$$\rho = \frac{w}{g} = \frac{64}{32.2} = 1.99 \text{ slugs/ft}^3$$

$$V = \text{velocity, feet/sec.}$$

For 22 mph

$$V = \frac{22}{60} \times 88 = 32.3 \text{ ft/sec}$$

$$q_{max} = \frac{1}{2} \times 1.99 \times (32.3)^2$$

$$= 1035.92 \text{ PSF}$$

$$= 7.2 \text{ psi}$$

4.6.5.2 Bow Flap

The HWSTD Bow Flap shall be of the configuration shown in Figure 4.6.5-1 in the deployed position and shall be 106 inches in width. The bow flap shall be designed to withstand the hydrodynamic loads in the deployed position. The hydrodynamic loads are defined in terms of 1) Plate Loads which are applied locally to the plates only for determination of plate strength and stiffness and 2) structural loads which are employed for conducting stress analyses of the bow flap supporting structure, struts, hinges/actuators and hull attachment points.

Plate Loads

The bow flap plate loads were developed using the "Heller-Jasper" method as detailed in Reference j. The plate loads as specified in Table 4.6.5-1 shall be applied to the upper and lower panels of the HWSTD bow flap. These loads shall be applied with a safety factor of 1.1.

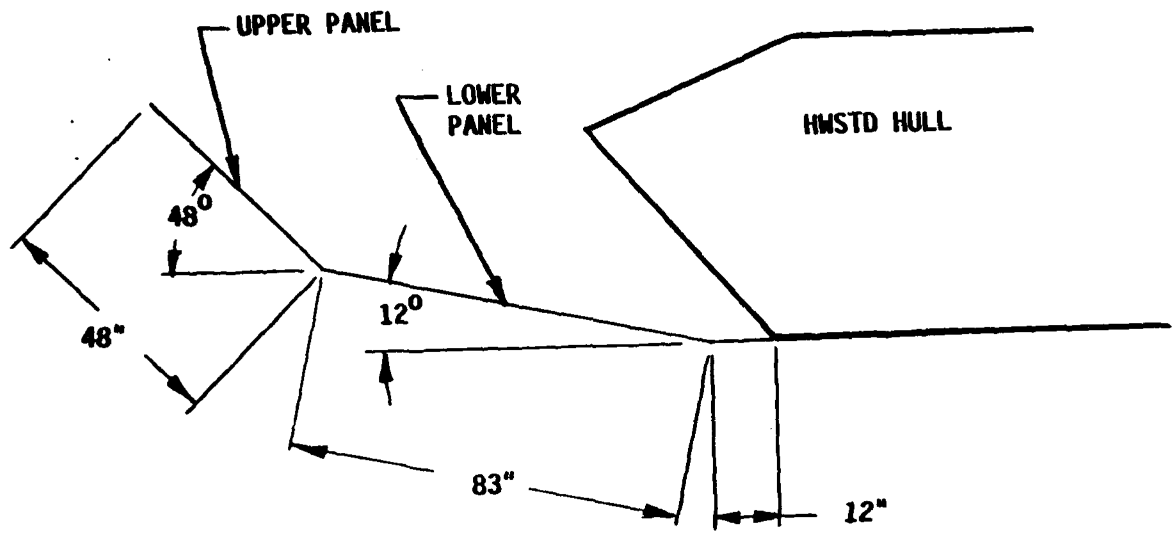

Figure 4.6.5-1 HWSTD Bow Flap Configuration

Structural Loads

The bow flap structural load is based upon loads derived from .55 scale model testing and consists of 41,704 and 41,399 pound loads applied simultaneously to the upper and lower panels of the bow flap, respectively. Each of these loads is applied at the center of the panel and acts in an up/rearward direction. These loads if distributed over the surface of the panels are equivalent pressures of 8.1 psi on the upper panel and 4.7 psi on the lower panel. These loads shall be applied with a 1.1 safety factor.

4.6.5.3 Hull

The HWSTD hull structure shall be designed to withstand the hydrodynamic loads as specified in Table 4.6.5-1. These load pressure distributions were developed using the "Heller-Jasper" method as detailed in Reference j. These loads shall be applied with a safety factor of 1.1.

The HWSTD hull structure shall be designed to withstand the appendage loads applied to it at the appendage attachment points. The appendage loads transmitted into the hull include the bow flap structural loads, the chine flap structural loads, side skirt loads, and the transom flap loads. These loads shall be applied independently with a 1.1 safety factor.

Hull appendages, the bow flap, chine flaps, and transom flap shall be deployed and retracted using a power system. Deployment and retraction will be accomplished only at vehicle zero water speed. Deployment or retraction of these appendages shall be accomplished in approximately one minute. Chine flaps shall be provided with a mechanical locking feature in the deployed position that engages and locks with the side skirts.

4.6.5.4 Side Skirts

The side skirts shall be designed to support the loadings resulting from support of the suspension system weight in the retracted mode and the chine flap structural load applied to the chine flaps during high speed water operations with a safety factor of 1.1 applied.

The suspension system loading in the retracted mode equals the following:

Retracted Suspension System Weight

1/2 weight of 6 roadarm assemblies	=	184 lbs
Weight of 12 roadwheels	=	349 lbs
Weight of full track length/side	=	1331 lbs
Total supported weight	=	1864 lbs/side

Table 4.6.5-1 Bow Flap Plate, Hull and Chine Flap Hydrodynamic

Longitudinal Load Distribution

Surface	Pressure (PSI) Forward Edge to Rear Edge With Linear Change in Between
Upper Bow Plate	9 to 13
Lower Bow Plate	13 to 16.3
Hull Bottom	16.3 to 10.3

Traverse Load Distribution

Distance	Pressure (%) As a percentage of the longitudinal load pressure with the load being symmetrical about centerline
Centerline to 1/2 Girth	100
1/2 Girth to Outboard Edge	100 linearly decreasing to 80 at the outboard edge

Note: The total girth of the vehicle should be based upon the total planning width (106 + 24 = 130 inches). This means the pressure at the outboard edges of both the bow and transom flaps will be greater than 80%.

Chine Flap Structural Load

$$\text{Chine Flap Lifting Pressure} = \frac{\text{GVW}}{\text{Hull Bottom Area plus Chine Flap Area}}$$

$$= \frac{35{,}000}{(201 \times 64.25) + 2(32.88 \times 201)}$$

$$= \frac{35{,}000}{12914 + 13216}$$

$$= 1.34 \text{ psi}$$

Chine Flap Lifting Force = (1.34 x 13,216)/2

= 8,855 lbs/side

Chine Flap Structural Load = 2g x Lifting Force

= 17,710 lbs/side

Both the suspension and chine flap structural loads shall be distributed on a geometric basis between the side skirts and the hull.

Side skirts shall be designed in sections that can be handled by two men.

4.6.5.5 Chine Flaps

The chine flaps shall be designed to withstand the hydrodynamic loads applied while in the deployed position and locked to the side skirts. The hydrodynamic loads are defined in terms of 1) plate loads which are applied locally to the plates only for determination of plate strength and stiffness, and 2) structural loads which are employed for conducting stress analysis of side skirt column strength and adequacy of the hull/actuator attachment.

Plate Loads

The deployed chine flaps shall be designed to support the plate loads resulting from support of the suspension system weight in the retracted mode and the "Heller-Jasper" loads per Table 4.6.5-1 applied to the lower surface of the chine flaps with a safety factor of 1.1.

Structural Loads

The deployed chine flaps shall be designed to withstand the average chine flap lift force under a 2g acceleration equal to 17,710 lbs/side as derived in Section 4.6.5.4. This force shall be employed to determine the structural adequacy of the side skirt column strength and the hull/actuator attachment of the chine flaps.

Actuator Loads

The chine flaps and actuators on each side of the vehicle shall be designed to lift one-half (1/2) of the track weight (0.5 x 1331 = 665 lbs) during deployment actuation. These loads shall be applied with a 1.1 safety factor.

4.6.5.6 Transom Flap

The transom flap, actuators and attachment supports shall be designed to resist the simultaneous application of thrust and lifting forces of the magnitude location and direction as specified in Figure 4.6.5-2. These loads shall be applied with a 1.1 safety factor.

The transom flap, actuators and attachment supports shall also be designed to resist the above simultaneous loads with the thrust load vectored either 45° to the starboard or port side. These loads shall be applied with a 1.1 safety factor.

4.6.6 Transportation Loads

Transportation of the HWSTD will be accomplished only by truck. The structural loadings associated with this mode of transport will not exceed the structural design loads defined for land and water operations.

4.6.7 Operator Applied Loads

The HWSTD shall be designed for the following operator applied loads.

Foot operated controls - 750 pounds

Hand operated push-pull controls - 150 pounds forward and aft, 75 pounds side to side.

Seats - 180 pound man with load factors defined in Section 4.6.4.3.

4.7 WATERTIGHTNESS

All HWSTD joints, hatches, access covers and rear ramp shall be waterproof. For watertightness during water mode operations the HWSTD shall be equipped with the following items.

A device to seal the land mode cooling air intake and outlet.

A portable fabric cover to further seal the land mode cooling air intake and outlet during water towing operations.

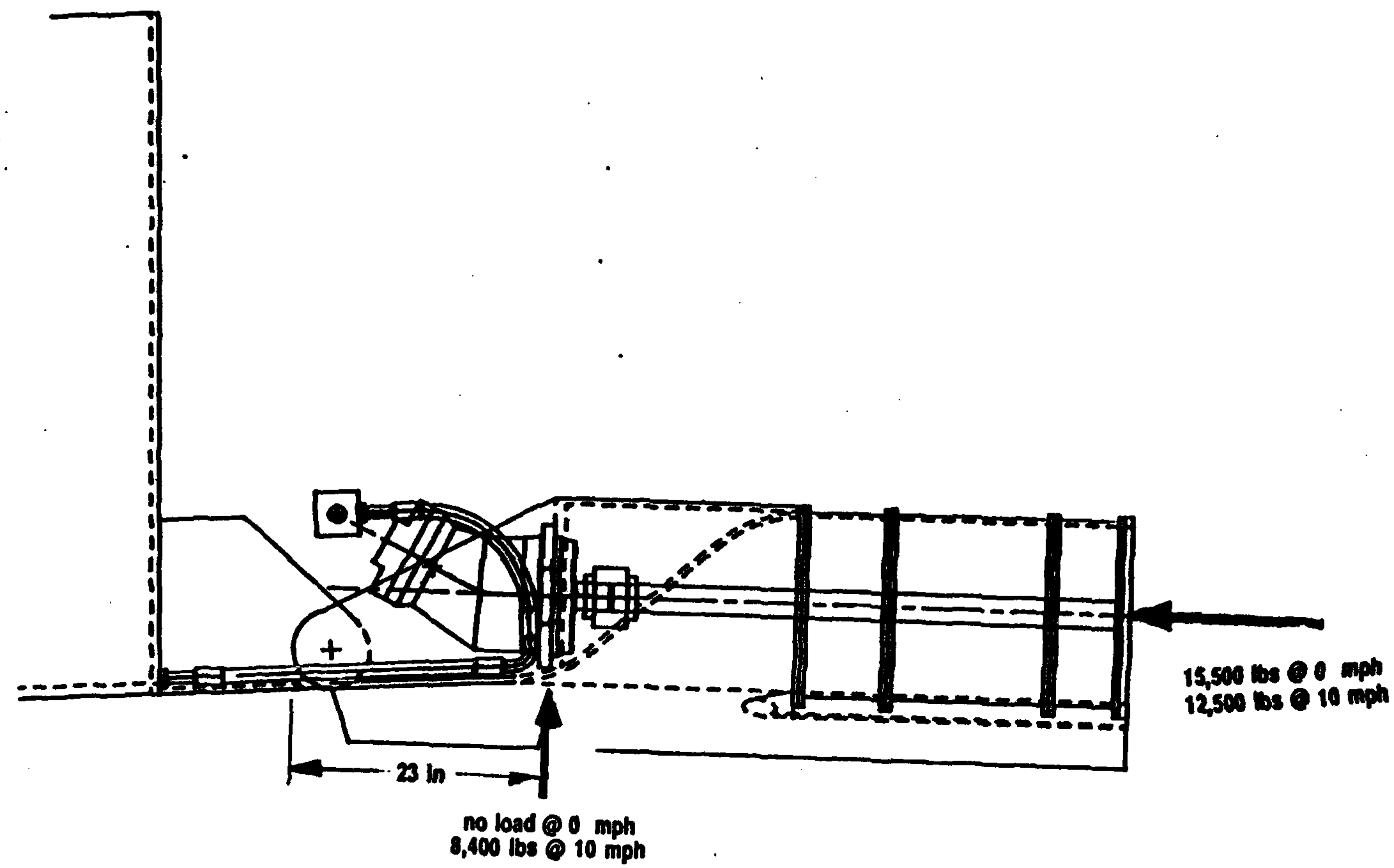

Figure 4.6.5-2 Transom Flap Loads

A simple mechanical flapper valve in the engine air induction system to preclude water spray entry during water operations.

A bilge pump system similar to that employed in the ATR.

A rear ramp seal and latching system.

Covers on bilge pump discharge ports.

4.8 OPERATING ENVIRONMENT

The HWSTD shall be designed for operation in the following conditions:

Temperature - Operable at 20°F to 98°F. Operable in 70°F seawater.

Altitude - Sea level.

Sea Conditions - Operable in Sea State 2. HWSTD shall not be adversely affected by prolonged exposure to a saltwater environment.

Water Immersion - Operable during and following complete submission in saltwater.

Rain/Dust/Humidity - Operable after exposure to moderate amounts of rain, dust, sand or extremes of humidity.

Vibration - Track induced up to 118 Hz.

Terrain - Operable on paved roads, secondary roads, trails and in moderate cross-country conditions without significant vegetation and obstacles. Land speed range of 10 to 20 mph.

Max. slopes - 17% during water ingress/egress. 10% continuous land operation.

Cooling system/engine performance temperature design criteria:

Land Mode

Ambient Air	98°F
Fuel	118.4°F

Water Mode

Ambient Air	98°F
Fuel	80°F
Sea water	70°F

4.9 *OPERATIONAL DURABILITY*

The components and materials selected for and the design of the HWSTD shall be directed toward achieving a testing life of 600 hours without major maintenance actions. For design purposes and selection of components the following daily testing schedule can be assumed.

Engine idle - 2 hours/day

Land operations - 1/2 hour/day

Transition operations - 1/2 hour/day

Water operations - 2 hours with 2 ingress/egress maneuvers and appendages deployment/retractions.

Total operation - 5 hours/day

Total operating hours - 5 hours/day x 15 days/month x 4 months/yr. x 2 years = 600 hours.

5.0 DESIGN DOCUMENTATION

Documentation of HWSTD design and program activities will be provided in the following documents:

Document	Contract Data Item
Design Requirements Report	---
Design Report	A001
Engineering Drawings	A002
Project Milestone Chart	A003
Monthly Progress Report	A004
Test Plan (AAI Testing)	---
Fabrication and Test Report	B001
Engineering Drawings (updated)	B002
FMECA Report	B003
Operation and Maintenance Manual	---
Government Test Support Report	C001

6.0 REFERENCES

The following documents were used to develop the HWSTD design requirements:

a. Section C of DTNSRDC Contract N00167-87-C-0033, dated 27 February 1987.

b. AAI HWSTD Technical Proposal, ER-14469, dated July 1986.

c. AMC Handbook, AMCP706-357, Engineering Design Handbook, Automotive Series, Automotive Bodies and Hulls, dated April 1970.

d. HSTV(L) Design Criteria, AAI Report ER-9356 (Rev. A), dated 11 April, 1978.

e. ATR Design Criteria, AAI Report R-60011-00002, dated 5 March, 1984.

f. HWSTD Hydrodynamics Presentation, presented 11 March, 1987 by Mr. John Hoyt, DTNSRDC.

g. HWSTD Waterjet Power Requirements, provided 27 March 1987 by Mr. John Stricker, DTNSRDC.

h. MTU Provided 883 Engine data and characteristics.

i. MAR INC. Report No. 558, "High Water Speed Technology Demonstrator Concept Design Analyses", April 1986.

j. AAI Conference Report dated 12 June 1987 containing "On the Structural Design of Planing Craft" by S. R. Heller, Jr., Commander, U.S.N. and N. H. Jasper, Dr. Engrg.

k. AAI Conference Report dated 17 June 1987 containing "Heller-Jasper" Loads applicable to the HWSTD.

l. AAI Conference Report dated 17 July 1987 deriving Bow Flap Structural Loads.